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CALIBRATION OF THE STRATOSPHERIC AITKEN NUCLEI DETECTION SYSTEM--ETC(U)
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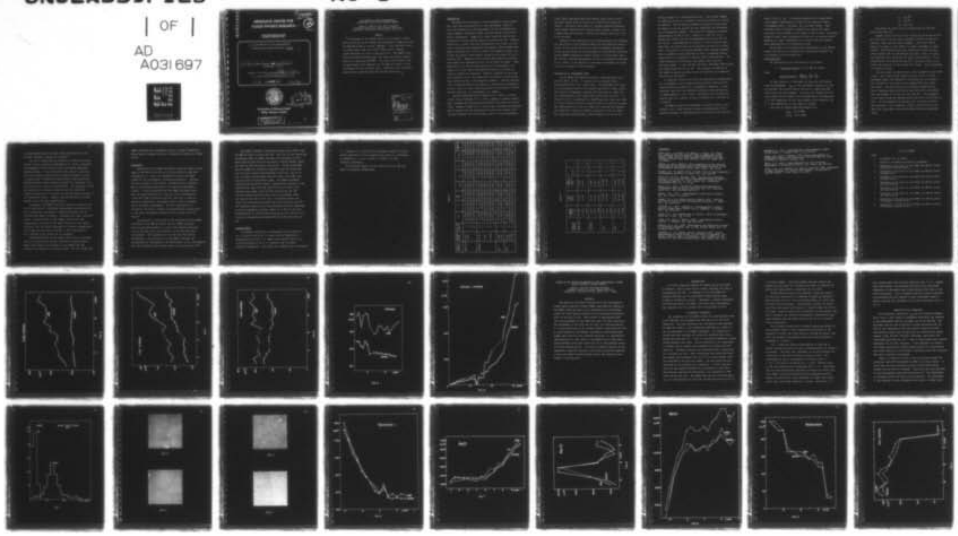

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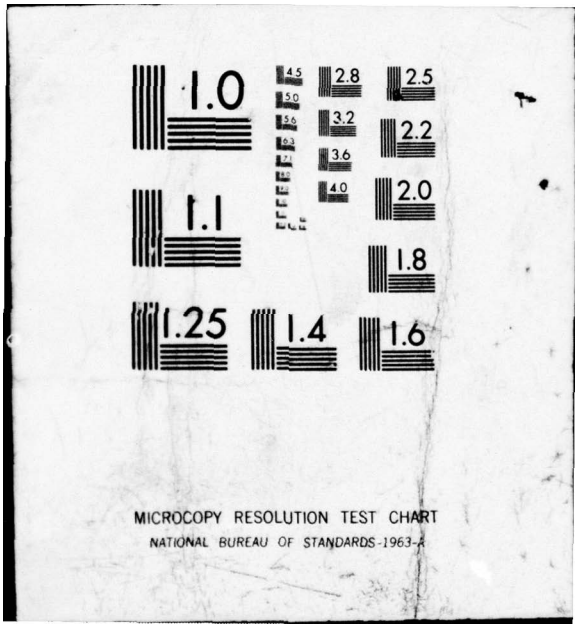
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(6) CALIBRATION OF THE STRATOSPHERIC AITKEN NUCLEI DETECTION SYSTEM (SANDS).

(10) James E. Wegrzyn and Josef Podzimek
(GCCPR-UMR, Rolla)

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CALIBRATION OF THE STRATOSPHERIC AITKEN NUCLEI DETECTION SYSTEM (SANDS)

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SUMMARY

Calibration of the General Electric Stratospheric Aitken Nuclei Detection System (SANDS) was performed by comparison with the UMR Aitken Nuclei counter (UMR ANC). Four different sources of Aitken nuclei (AN) were used, namely room aerosol, propane, sodium chloride and silver iodide particles. The SANDS instrument proved good reproducibility and high sensitivity (approximately five particles per cm^3). The counts were usually lower by approximately 30% compared with the UMR AN counter, if the Instrument Unit was operated alone. Additional 12% losses were measured when operating with the Pressurization Unit.

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INTRODUCTION

Reviewing the literature on the stratospheric Aitken nuclei (AN) since the pioneering work by Gish and Sherman (1935) or since the publication of AN measurements in the stratosphere by Junge, Chagnon, and Manson (1961), we find several often controversial conclusions. Junge et al (1961) found the mean AN concentration at 20 km altitude about one particle per cm^3. However, Friend et al. (1973) took into consideration the results of radiation scattering and transmission measurements which yielded much higher concentrations of AN in similar stratospheric levels (e.g. de Bary and Rossler, 1970 found a concentration around 10^4 particles per cm^3). Remsberg (1972) analyzed some physical processes which might have affected the very low AN counts by Junge. Junge measured AN in a counter which adjusted the stratospheric air sample to 0.5 Atm. above the ambient pressure by injection of clean air before the expansion. Remsberg attempted to show that this procedure led to the evaporation of sulfuric acid AN before they could be active in the expansion chamber. Although Jaenicke (1973) corrected some of the numerical calculations in Remsberg's article, there are still some uncertainties concerning the effect pressurization has on stratospheric air samples.

Recently published data by Hoppel et al. (1973), by Rosen (1974), and by Podzimek et al. (1974), support in general Junge's data, although the measured concentrations were higher in several cases. However, Hoppel et al. (1973) used a standard Environmental One AN Counter with the pressurized air from the airplane cabin and they measured only in the lowest levels of the stratosphere.

Rosen (1974) determined particles smaller than 0.1μm by counting liquid drops grown on nuclei in a photoelectric particle counter. The nuclei were grown in a thermal gradient diffusion cloud chamber operated with ethylene glycol vapors. Rosen's instrument was carried under a balloon and sampled nuclei up to 20-25 km altitude.

Because of the importance of the AN measurements for checking the feasibility of the proposed models for the generation and behavior of the aerosol particles in the stratosphere and because of the special design of the Stratospheric Aitken Nuclei Detection System (SANDS) designed by General Electric in Pittsfield, Mass., and used for airplane measurements in the stratosphere by Podzimek et al. (1974), it was decided to investigate thoroughly the function of this counter in the laboratory.

DESCRIPTION OF INSTRUMENTS USED

The GE SANDS instrument has recently been described in detail by Haberl (1975). It consists of an Instrument Unit, a Pressurization Unit and a Control Box. The Instrument Unit (Fig. 1) is principally based on the counter described by Skala (1963), with special arrangements enabling the instrument to count very low concentrations of AN (lower than 10 particles per cm^3). Detection of AN is accomplished by condensing water vapor upon them to create visible-sized water droplets which are optically sensed. The supersaturation of the air sample for starting the condensation upon AN is caused by adiabatic expansion of the air which was originally drawn through a probe assembly into one of two

holding chambers in a Pressurization Unit. The holding chamber is sealed and clean air is added to raise the pressure to 730 mm Hg absolute. The two holding chambers alternate in delivering 30 samples of air per minute into the humidifier and afterwards into the expansion chamber. The process of expansion, leading approximately to 330% of R.H., repeats at a rate of 2.5 air samples per second with the corresponding flow rate of 200 cm^3 per second. A photomultiplier produces a train of pulses whose amplitudes are proportional to AN concentration and it's surface area. The pulses are processed through a peak reading voltmeter with an automatic range switching to yield a continuous analog output which is calibrated to indicate nuclei concentration. The range-switching circuits select the proper scale from the following ranges: 0-100; 100-300; 300-1000; 1000-3000; 3000-10,000; and 10,000-60,000 nuclei per cm^3. The original calibration of the SANDS instrument was made in the GE laboratory by comparison with Pollak's AN counter.

In addition, particle size data are obtained by incorporation of a programmed series of precipitating electric potential differences which are applied to a cylindrical condenser. In the condenser, particles are removed according to their mobilities, or, approximately to their sizes. The function of the mobility analyzer was not a subject of this calibration so it was not investigated.

The UMR AN counter was described in several articles (e.g. Kassner et al., 1968) and was recently used during the International Workshop on Condensation and Ice Nuclei in Fort Collins

(Grant, 1971; p. 34). It consists basically of a large Wilson cloud chamber (approximately 18,000 cm^3 of sampling volume), a Programming Unit, a Recorder, and a Pressure Gauge. Eight different rates of adiabatic expansion can adjust the super-saturation in the chamber in the range of 180% to 400%. The drops, formed by water vapor condensation on the AN, are directly photographed in a space illuminated by two flash tubes and counted after magnification on a projection screen.

The accuracy of AN concentration measurements by the UMR AN counter and the errors introduced by counting the droplets can be estimated in the following way:

Error Analysis:

The concentration was determined by the formula

$$N = n\left(\frac{1}{\text{Dilution Factor}}\right) \text{ for the UMR AN counter}$$

where

$$\frac{1}{\text{Dilution Factor}} = \frac{P_{atm}}{(P_a - P_b)} \left(\frac{h_e}{h_c}\right) \left(\frac{T_c}{T_s}\right).$$

In this formula n is the number of drops per cm^3 counted from the photograph. P_{atm} is the atmospheric pressure; P_a and P_b represent the pressure before and after a sample has been vented into the cloud chamber. h_c and h_e are respectively the total height of the chamber and its height after the expansion. T_c is the temperature of the cloud chamber after sampling, and T_s is the temperature of the sample in storage.

The error in taking these measurements are:

P_{atm}: ± 0.25 mmHg

$P_a - P_b$: ± 0.25 mmHg

T_c: $\pm 0.25^{o}C$

T_s: $\pm 0.1^{o}C$

h_e: ± 0.1 mm.

This makes the total error in determining the dilution factor less than $\pm 2\%$.

Another source of error is the statistical error due to the fact that only a sixteen cubic centimeter volume of drops was counted, rather than the entire chamber. This error can be shown to be equal to $\pm\sqrt{n}$, where n is again the number of drops counted. The dilution factor was controlled to keep the drop counts between 200 and 300 whenever possible. This, of course, was impossible when measuring the lower concentrations. For a concentration of 50 particles per cm^3, a dilution factor of 8:1 yields 100 particles in the sixteen cm^3 volume. This corresponds to an error of $\pm 10\%$.

The last source of major error is the alignment of the flash system. This flash system, which consists of two 1 cm wide collimated beams, was adjusted so that there was no overlap of the two beams in the center of the chamber where the counts were taken. The flash system was considered aligned if the entire counting region overlap was less than half a millimeter. This corresponds to an error of less than $\pm 3\%$. The alignment of the flash system was checked before and after every series of runs. If the alignment did not meet this criteria, the data were excluded. This, therefore, yields a total error of less than $\pm 15\%$, which makes the data obtained from this experiment valid.

AEROSOL GENERATION AND STORAGE

After generation, the aerosols were stored in a 2.1 x 2.1 x 3.6 m^3 airtight room (Fig. 2), which had an inflatable mylar bag installed inside. This large volume storage facility allowed a comparison of both counters to be made over long periods of time at a uniform concentration of AN. Also the moveable mylar bag was used to flush the old aerosol out, before filling it with a new type of aerosol.

Four different types of aerosols were used in this calibration testing. The initial test was done on a residual storage room aerosol that remained in suspension for several days. For higher concentration testing, a small amount of liquid propane was sprayed into the storage chamber. Sodium chloride was the third type of aerosol used, and it was generated by vaporization of NaCl crystals in a tungsten boat. After generation the NaCl aerosol passed through a series of low efficiency filters before storage. Finally, several tests were made on silver iodide aerosol which was drawn through some low efficiency filters before storage. This silver iodide aerosol was generated by burning a pyrotechnic mixture of AgI. The smoke from this mixture contains certainly more than just AgI nuclei.

In order to dilute the concentrations, clean nitrogen gas was mixed with the aerosol sample. By using the micro-metering valve, the concentration of aerosol could be controlled from the ambient concentration in the storage room to less than ten

particles per cm^3. In all cases, the aerosol was allowed to age for at least one day. This permitted the aerosol to disperse uniformly and was also long enough for the larger nuclei to settle out.

The different natures and size spectra of generated nuclei, as well as different flow systems in the two instruments explain the slight deviations in the ratio of AN measured by SANDS to that measured by the UMR AN counter. The AN losses were different for water soluble and insoluble nuclei that for polydisperse and monodisperse nuclei. It was found in the case of NaCl particles, that most of the larger particles were activated and lost before reaching the expansion chamber. On the other hand, it was found in the case of AgI nuclei that during one series of measurements not all nuclei were activated in the UMR AN counter, even at a supersaturation of 230%.

EVALUATION OF THE MEASUREMENTS

The simultaneous measurement of selected concentrations of room air, propane impurities, sodium chloride, and silver iodide (pyrotechnic mixture) aerosols, were plotted in diagrams similar to those in Fig. 3, 4, and 5. The individual points in the diagram correspond to separate measurements of the SANDS without the Pressurizing Unit. They were measured at time intervals sufficiently long to insure steady state concentrations of the stored aerosol. Because of the apparent proportionality of the data from the SANDS instrument (Y) to the UMR AN counter (X), simple linear regression analysis was used in which the predicted

value of the concentration measured by SANDS instrument ($\hat{Y}$) is given by

$$\hat{Y} = b_0 + b_1 X.$$

b_0 and b_1 are determined according to the relationships

$$b_1 = \frac{\Sigma(X_i - \bar{X})\ (Y_i - \bar{Y})}{\Sigma(X_i - \bar{X})^2}\ ;\ b_0 = \bar{Y} - b_1 \bar{X},$$

Where all summations are from i = 1 to n and X is the given value measured by the UMR AN counter. Estimated standard error of the predicted reading of the SANDS instrument ($\hat{Y}$) at a specific value X_k, then, is

$$\text{E.S.E.} = S\left[\frac{1}{n} + \frac{(X_k - \bar{X})^2}{\Sigma(X_i - \bar{X})^2}\right],$$

where

$$S^2 = \frac{\Sigma(Y_i - \bar{Y})^2}{(n-2)}.$$

As a simple measure of the response of the SANDS instrument compared to the UMR AN counter, the correlation coefficient used was

$$r_{xy} = \frac{\Sigma(X_i - \bar{X})\ (Y_i - \bar{Y})}{[\Sigma(X_i - \bar{X})^2]^{\frac{1}{2}}[\Sigma(Y_i - \bar{Y})^2]^{\frac{1}{2}}}.$$

Parameters b_0, b_1, E.S.E., and r_{xy} were calculated separately for AN concentration ranges of 0-100, 100-300, and 300-1000 particles per cm^3 because of separate electronic amplifiers for each of the ranges mentioned. Concentrations higher than 1,000 particles per cm^3 were also compared; however,

for stratospheric AN counts, these concentrations were not applicable.

The results of the calibration are summarized in Tab. I which is based on the comparison of 156 individual measurements. The measurements are divided into four groups according to the different types of nuclei and each of these groups is further divided into three subgroups. The different AN concentration ranges were not complete in the case of room air and AgI nuclei (only data for concentration ranges of 0-100 and 100-300 are available). The number of parallel measurements is different for individual types of nuclei and concentration ranges and varies between 6 and 41. In general, the SANDS instrument counts lower concentrations of AN than the UMR AN counter. The ratio of the respective AN concentrations is approximately 0.70, with the lowest mean value being 0.5436 for NaCl nuclei. The highest ratios were found in the case of room air and propane aerosol. The value of 0.613 for AgI aerosol at the concentration range between 0-100 suggests that some of the nuclei generated from the pyrotechnic mixture were large, had a hygroscopic nature, and for these reasons were deposited on the walls without reaching the expansion chamber.

Correlation factor r_{xy} was used as a measure of the response and reproducibility of the measurements with both counters. The smallest correlation factors (0.7730 and 0.7247) were found in one case of room aerosol and in sampling NaCl aerosol. At this time, these discrepancies cannot be satisfactorily explained. They could be caused by deficiencies in aerosol sampling or by

the change in sensitivity due to a drop in chamber temperature. Estimated standard errors (E.S.E.) support the suitability of linear regression analysis for the calibration of the SANDS instrument. However, in several cases, there were larger deviations from this rule (39.3% in one case of NaCl nuclei).

For estimation of the losses of AN in the Pressurization Unit, tests were performed in the GE laboratory by Mr. Haberl. Room aerosol was drawn into the counter both with, and without the Pressurization Unit. In the case of very high concentrations (up to 60,000 particles per cm^3), diffusional losses were found to be 8.12%; at a concentration between 3,000-10,000 particles per cm^3, losses were 14.38%; at 1,000-3,000 particles per cm^3 -- 11.75%; at 300-1,000 -- 12.80%, and between 0 and 300 particles per cm^3 losses were 11.96%. In general, the nuclei losses in the Pressurization Unit did not surpass 15% of the measured concentration. The direct investigation of AN losses in the Pressurization Unit in the stratosphere was not performed.

REMARK ON THE OPERATION OF THE SANDS INSTRUMENT IN THE STRATOSPHERE

The necessity of air compression brings several problems with it, which must be carefully analyzed. There is no reason for lower AN counts due to the complete evaporation of sulfuric acid nuclei during the air compression. Smith et al. (1968) demonstrated that complete evaporation of tiny solution drops was impossible and the recent calibration of nuclei counters used in higher stratospheric levels (Cadle et al., 1974) supports this conclusion. There were no substantial differences

in measurements made by counters using pressurized air and counters working at ambient air pressure.

The use of compressed and filtered air from the aircraft engine, such as reported by Podzimek et al. (1974), introduces the dependence of the counts of AN on the engine compressor output pressure. It was found that this pressure could drop below the minimum required value at higher altitudes (>15 km) if engine power settings were reduced below climb conditions. Reduced absolute sample pressure resulted in a reduction of AN count values by a factor of two and more. The inaccuracy of the AN counter due to pressure reduction could be avoided by complete instruction of the pilot and the AN counter operator as to satisfactory limits. Another solution would be to provide another source of clean compressed air.

In general, the SANDS strip chart record is characterized by the high spread of individual measurements, particularly in the case when the instrument is rapidly switching from one concentration range to another. Excluding the range transition points, the mean values of the highest counts were used (approximately the mean of the upper one-third of the concentrations), and this might correspond to the best interpretation of the physical processes occurring in the Pressurization Unit (opening of the valves and air exchange).

The humidification of the sample could also be a possible source of error, mainly because insufficient humidification might cause slower nuclei growth in the chamber and thus decrease the intensity of scattered light. For this reason the

SANDS instrument has a permanent control of sample temperature, which showed a maximum variation in temperature during the flight of $4^{o}C$.

CONCLUSION

Calibration of the SANDS instrument, which was flown several times on the WB-57F aircraft up to an altitude of 65,000 feet (Podzimek et al., 1974), was performed to assess the SANDS capability for stratospheric airplane measurements: checking the fast response of the counter, reproducibility of measurements, and possible deviations of the data from the UMR AN counter. It was anticipated that the SANDS instrument would have very high sensitivity in order to count concentrations of AN lower than 10 particles per cm^3, and that it would be capable of operating in the higher levels of the troposphere and in the lower stratosphere. The last requirement was dictated by the need to measure the background AN concentration in the lower stratosphere before the SST airplanes start to operate.

In conclusion, it was found in the calibration of the SANDS instrument by the UMR AN counter that the SANDS instrument delivers many measurements in a short time enabling investigation of the fine layer type structure of the polluted lower stratosphere. The reproducibility of the data was entirely satisfactory. The sensitivity of the SANDS instrument was satisfactory for the purpose of AN measurements in the stratosphere, the lowest observed counts being around five particles per cm^3.

The SANDS instrument consistently showed lower counts than the UMR AN counter by more than 30%. This fact is not surprising considering that the SANDS instrument was adjusted a little lower than the mean level of AN counts by Pollak counter, which was used for the preliminary calibration. The AN counts made with the SANDS are furthermore dependent upon the nature and size of nuclei (larger and hygroscopic particles, such as in Fig. 5, always showed higher particle losses, over 40%), and upon the nuclei concentration range. The SANDS instrument, compared with the UMR AN counter, showed better response in the concentration range 300-1000 particles per cm^3 than in the concentration ranges 0-100 and 100-300 particles per cm^3. The new slightly modified version of the instrument, which was flown by the end of 1974, has a calibration which also covers the concentrations larger than 1,000 particles per cm^3. The estimated losses of AN in the Pressurization Unit operating at normal atmospheric pressure amount to 14.38% for particle concentrations of 3,000-10,000 particles per cm^3, and are close to 12% for concentrations between 300 and 1,000 particles per cm^3.

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TABLE I.

TYPE OF AEROSOL	CONCEN. RANGE	NO. OF CASES	$\bar{Y}$	$\bar{X}$	$\frac{\bar{Y}}{\bar{X}}$%	r_{xy}	b_0	b_1	E.S.E.	$\frac{\text{E.S.E.}}{\bar{Y}}$%
ROOM AIR	0-100	9	83.4444	117.9111	70.7690	0.8731	47.4140	0.8448	12.7436	10.8078
	0-300	7	112.4286	163.8571	68.6138	0.8860	-68.2323	2.0643	39.6355	24.1890
		18	195.7778	256.1665	76.4260	0.7730	57.0347	1.0171	15.5684	6.0775
		16	199.4375	299.5625	66.5762	0.9193	-908.4529	6.0571	87.6869	29.2716
PROPANE	0-100	12	49.7083	71.1333	69.8805	0.9680	-6.4861	1.5615	12.4409	17.4896
		9	55.3333	88.6667	62.4060	0.9495	26.7550	1.1189	10.1477	11.4448
	0-300	4	185.0000	311.0000	59.4835	0.9909	-30.0776	1.8437	60.6955	19.5162
		9	213.3333	317.2222	67.2504	0.9372	38.4299	1.3068	49.9861	15.7574
	0-1000	15	565.8665	684.8665	82.6244	0.9732	124.2644	0.9907	52.0342	7.5977
		9	705.1111	976.5554	72.2039	0.9964	50.1504	1.3138	146.0613	14.9568
A_gI	0-100	7	88.8571	145.0000	61.2808	0.8659	6.1535	1.5626	31.9411	22.0283
	0-300	13	179.4615	255.6923	70.1865	0.9901	25.9352	1.2803	21.1147	8.2579
NaCl	0-100	6	39.5000	72.6667	54.3578	0.9622	-19.7010	2.3384	28.5614	39.3047
	0-300	10	186.4000	317.2000	58.7642	0.9749	26.3367	1.5604	39.4253	12.4292
	0-1000	13	446.4614	651.2307	68.5566	0.7247	-178.2173	1.8578	51.4966	7.9076

TABLE II.

TYPE OF AEROSOL	CONCENT. RANGE N cm^3	$\frac{\sum_i \frac{X}{Y}\%N_i}{\sum_i N_i}$	$\frac{\sum_i \frac{ESE}{Y}\%xN_i}{\sum_i N_i}$	$\sum_i N_i$	i
ROOM AIR	0-100	70.769	10.806	9	1
	0-300	71.248	18.221	41	3
	0-1000	--	--	0	0
PROPANE	0-100	66.677	14.899	21	2
	0-300	64.861	16.914	13	2
	0-1000	78.717	10.357	24	2
A_gI	0-100	61.2808	22.0283	7	1
	0-300	70.1865	8.2579	13	1
	0-1000	--	--	0	0
NaCl	0-100	54.3578	39.3047	6	1
	0-300	58.7642	12.4292	10	1
	0-1000	68.5566	7.9076	13	1

REFERENCES

Cadle, R.D., G. Langer, J.B. Haberl, A. Hogan, J.M. Rosen, W.A. Sedlacek and J.E. Wegrzyn, 1974; A Comparison of the Langer, Rosen, Nolan-Pollak and SANDS Condensation Nucleus Counters, Prelim, Rep. NCAR, Boulder, also in J. Appl. Met. (in print).

deBary, E. and F. Rössler, 1970; Computation of the Particle Concentration from Measurements of Scattered Radiation in the Stratospheric Dust Layer, Beitr. Phys. Atmos., 43, 87-92.

Friend, J.P., R. Leifer and M. Trichon, 1973; On the Formation of Stratospheric Aerosols, J. Atmos. Sci., 30, 465-479.

Gish, O.H. and K.L. Sherman, 1936: The National Geographic Society - U.S. Army Air Corps Stratospheric Flight of 1935 in the Balloon Explorer II., Natl. Geogr. Soc., Washington Stratosphere Ser., No. 2, p. 94.

Grant, L.O., 1971: The Second International Workshop on Condensation and Ice Nuclei, Rep. Dep. Atm. Sci., Colorado State Univ., Fort Collins, May 1971.

Haberl, J.B., 1975: A Stratospheric Aitken Nuclei Counter, Rev. Sci. Instr. (in print).

Hoppel, W.A., J.E. Dinger and R.E. Ruskin, 1973: Vertical Profiles of CCN at Various Geographical Locations, J. Atmos. Sci., 30, 1410-1420.

Jaenicke, R., 1973: Comments on "Discrepancies in Stratospheric Aitken Nuclei Counts" by E.E. Remsberg, J. Geophys. Res., 78, 7159-7160.

Junge, C.E., C.W. Chagnon and J.E. Manson, 1961a; Stratospheric Aerosols, J. Met., 18, 81-108.

Junge, C.E. and J.E. Manson, 1961b: Stratospheric Aerosol Studies, J. Geophys. Res., 66, 2163-2182.

Kassner, J.L., Jr., 1968: Experimental and Theoretical Studies of Nucleation Phenomena, Rep. to NSF, GA-428, GCCPR, Univ. of Missouri-Rolla, Oct.

Podzimek, J., J.B. Haberl and W.A. Sedlacek, 1974: Recent Measurements of Aitken Nuclei in the Lower Stratosphere, Prel. Report. CIAP-U.S. Dept. of Transport., June; Summary in the Abstracts of the IVth Conference CIAP, DOT, Boston, Feb. 1975.

Remsberg, E., 1972; Discrepancies in Stratospheric Aitken Nuclei Counts, J. Geophys. Res., 77, 6014-6016.

Rosen, J.M. and D.J. Hofmann, 1974; Recent Measurements of Condensation Nuclei from Ground Level to 25 Km, Rep. No. CN-2, University of Wyoming, Laramie, Aug.

Skala, G.F., 1963: A New Instrument for the Continuous Measurement of Condensation Nuclei, Anal. Chem., 35, 702-706.

Smith, J.G., J.L. Kassner, Jr. and A.H. Biermann, 1968; Evaporation of Small Droplets in a Wilson Cloud Chamber: Properties of Residual Nuclei, J. Res. Atmos. 3, 41-44.

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Figure

1 Instrument Unit of SANDS.

2 Scheme of the SANDS calibration arrangement.

3 Comparison of AN counts by the SANDS and UMR AN counter for propane residual nuclei

4 Comparison of AN counts by the SANDS and UMR AN counter for AgI nuclei.

5 Comparison of AN counts by the SANDS and UMR AN counter for NaCl nuclei

6 Comparison of AN counts by the SANDS and UMR AN counter for room aerosol.

7 Comparison of AN counts by the SANDS and UMR AN counter for room aerosol.

8 Comparison of AN counts by the SANDS and UMR AN counter for room aerosol.

9 Comparison of AN counts by the SANDS and UMR AN counter for propane residual nuclei.

10 Comparison of AN counts by the SANDS and UMR AN counter for propane residual nuclei.

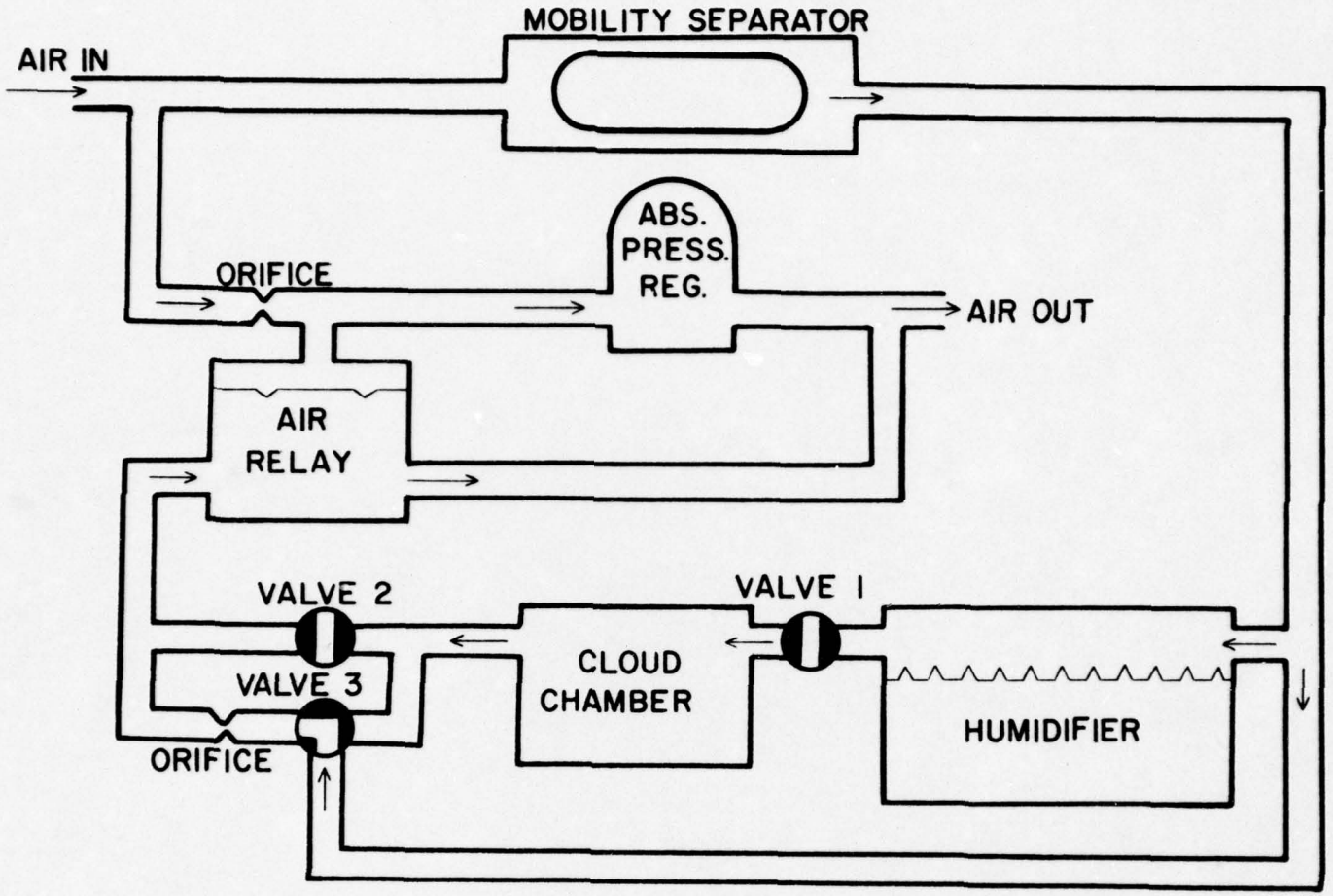
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FIG. 1

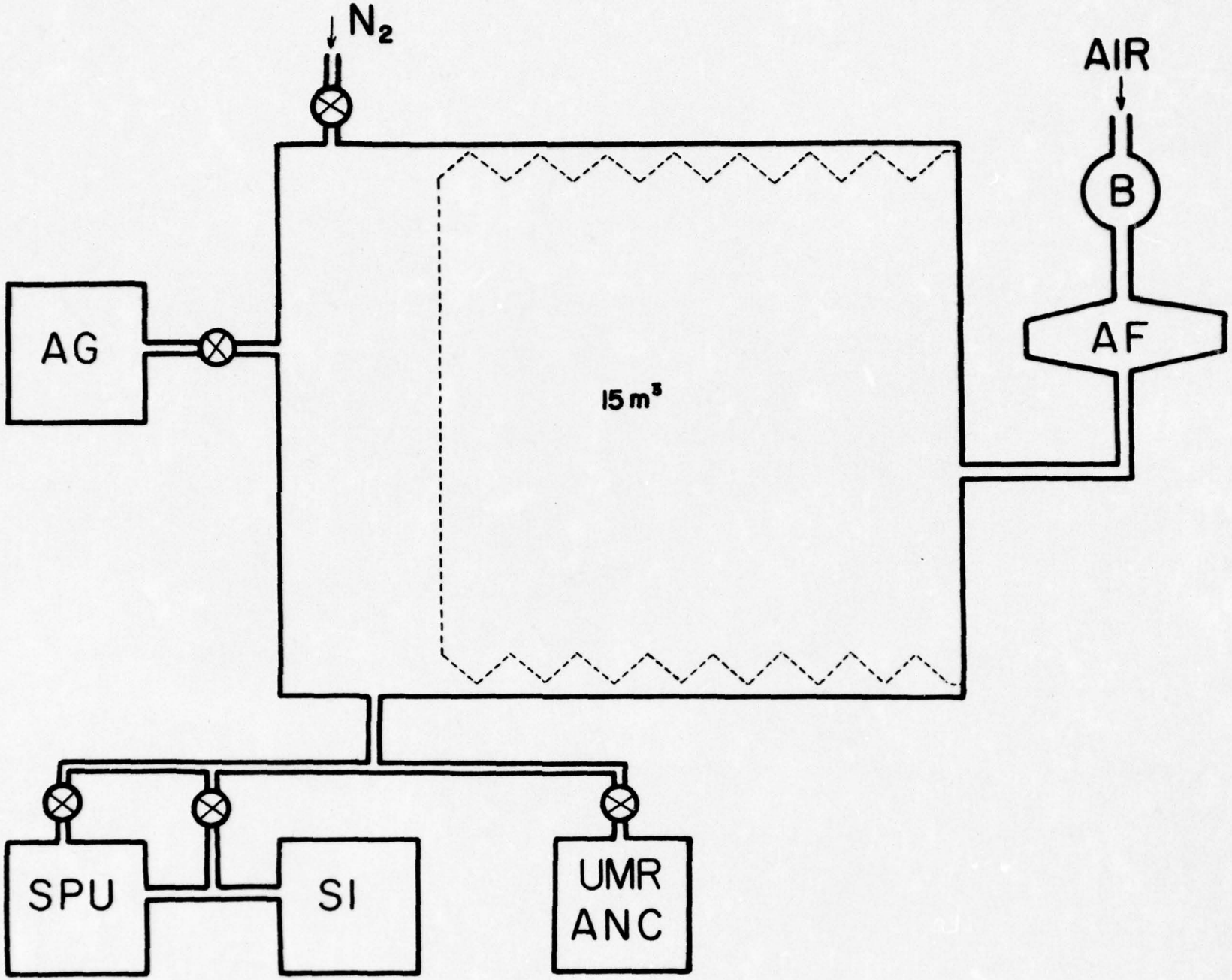

FIG. 2

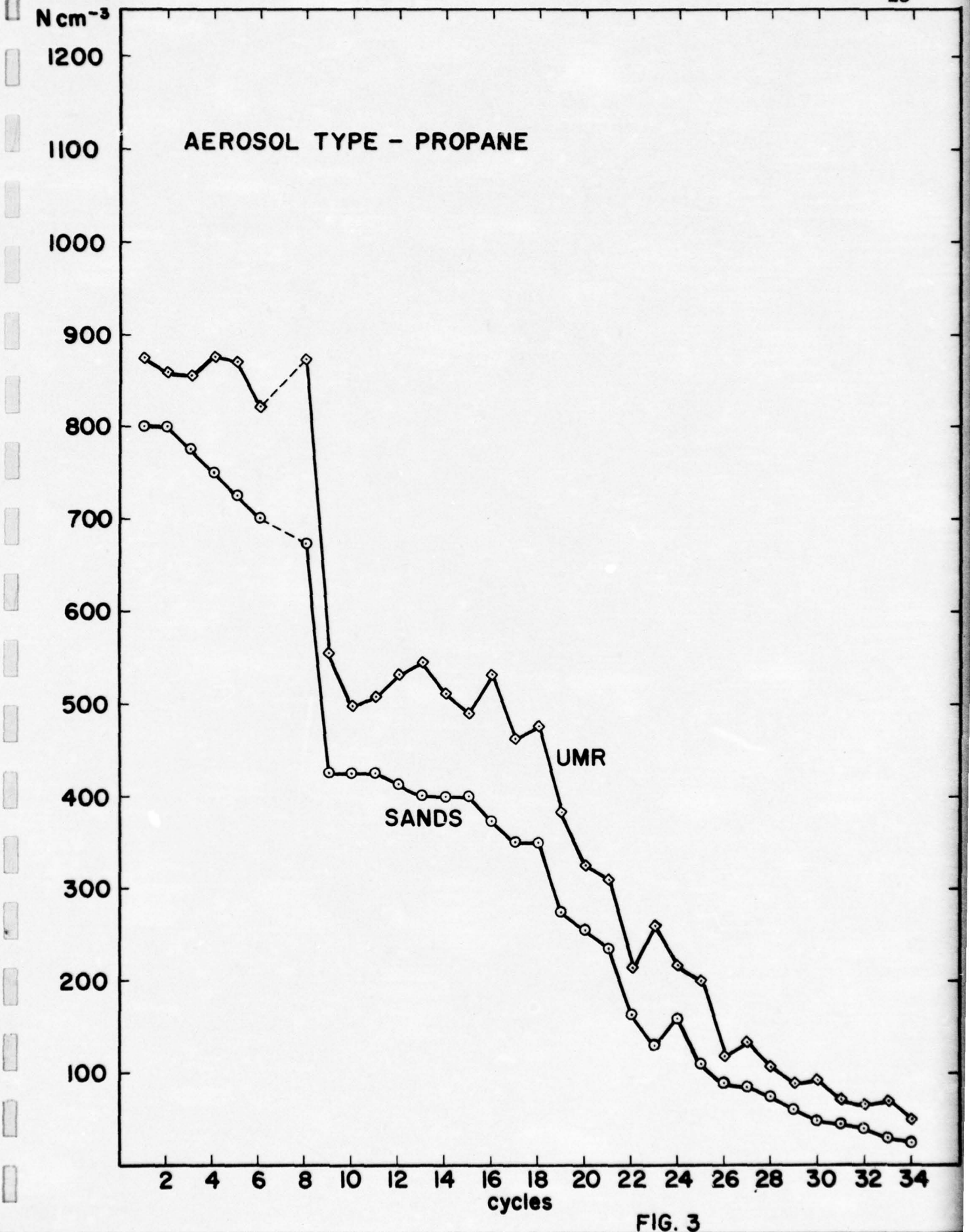
N cm⁻³
1200
1100
1000
900
800
700
600
500
400
300
200
100
AEROSOL TYPE - PROPANE
UMR
SANDS
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
cycles

FIG. 3

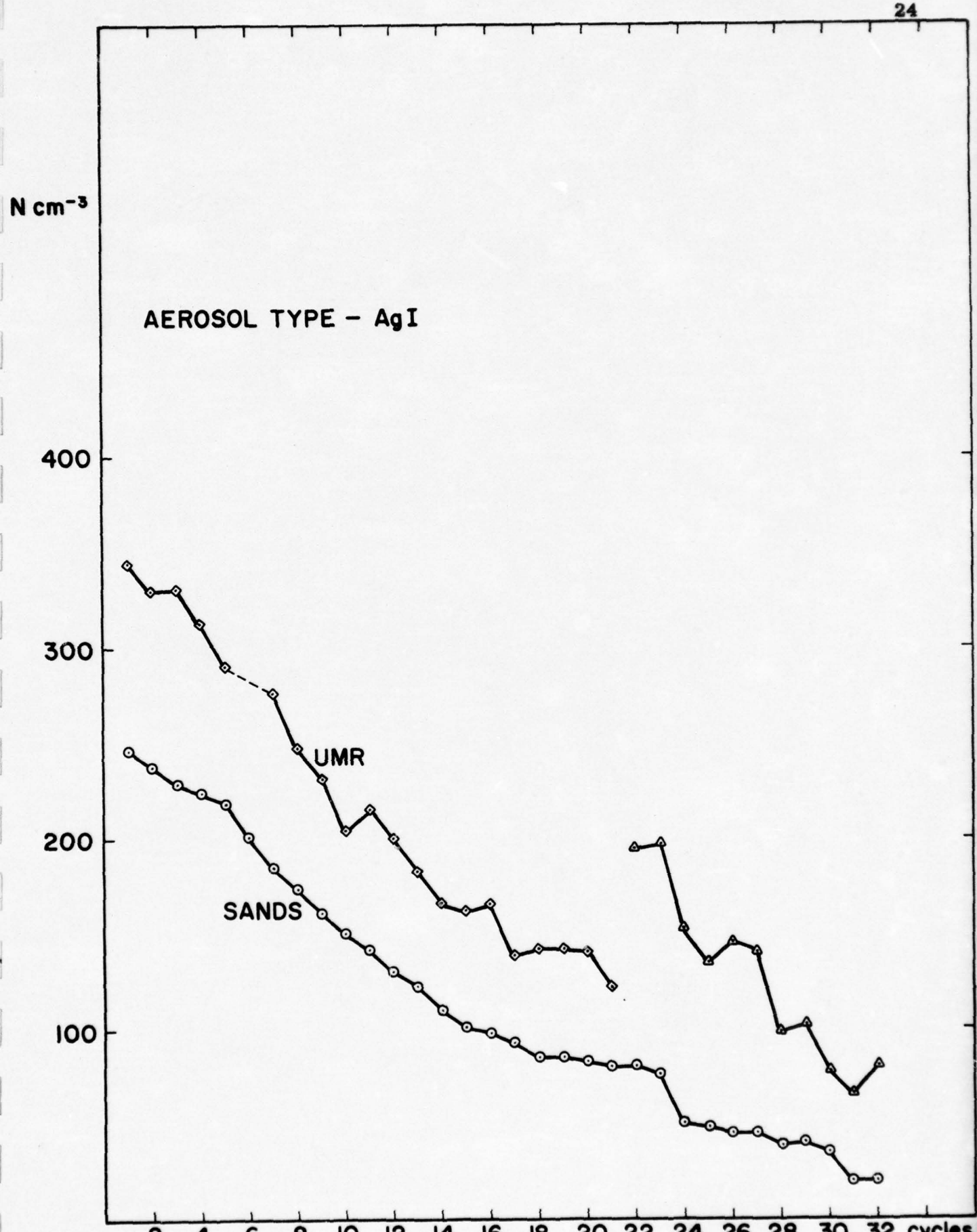
N cm⁻³
AEROSOL TYPE – AgI
400
300
200
100
UMR
SANDS
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 cycles

FIG. 4

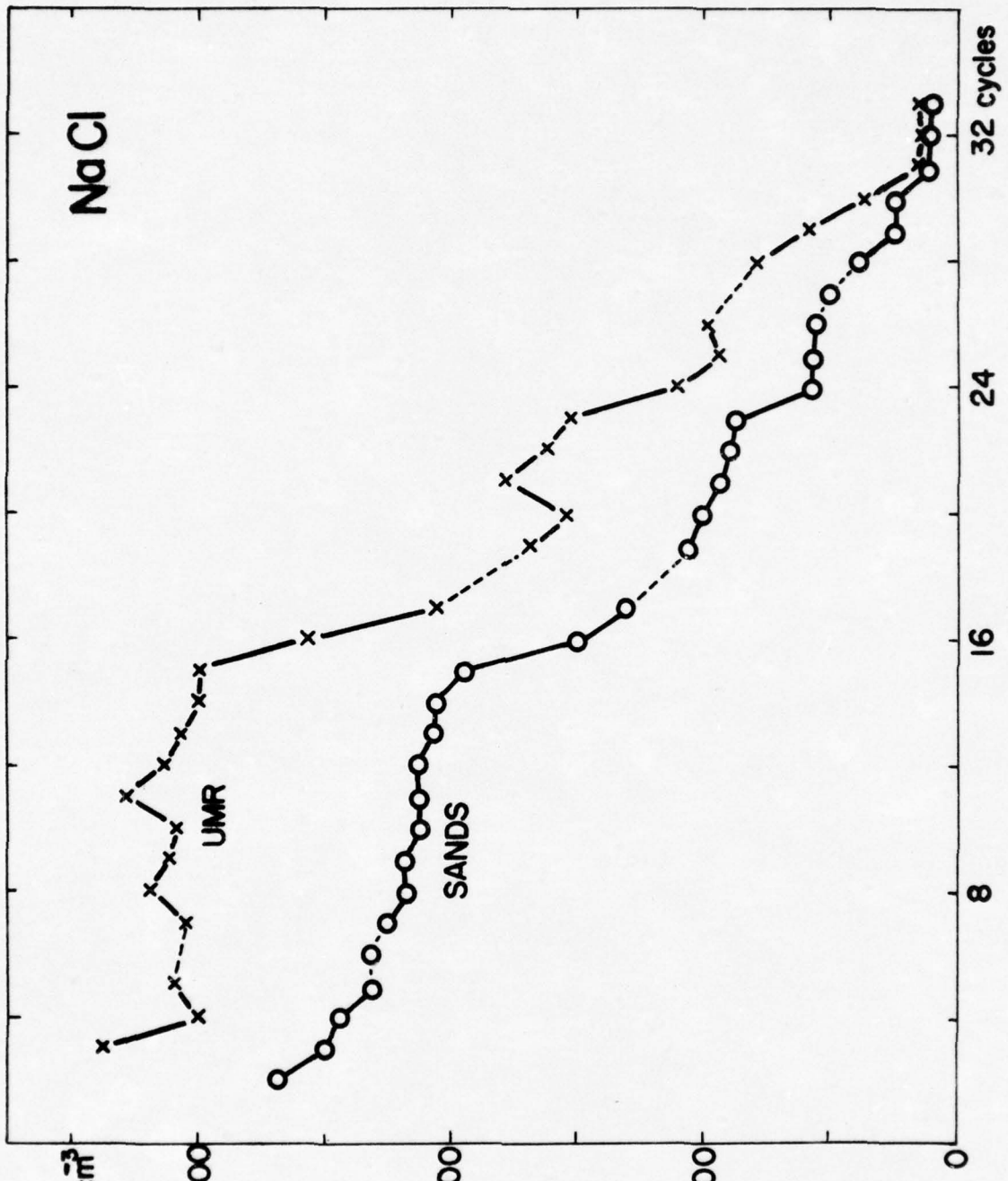

FIG. 5

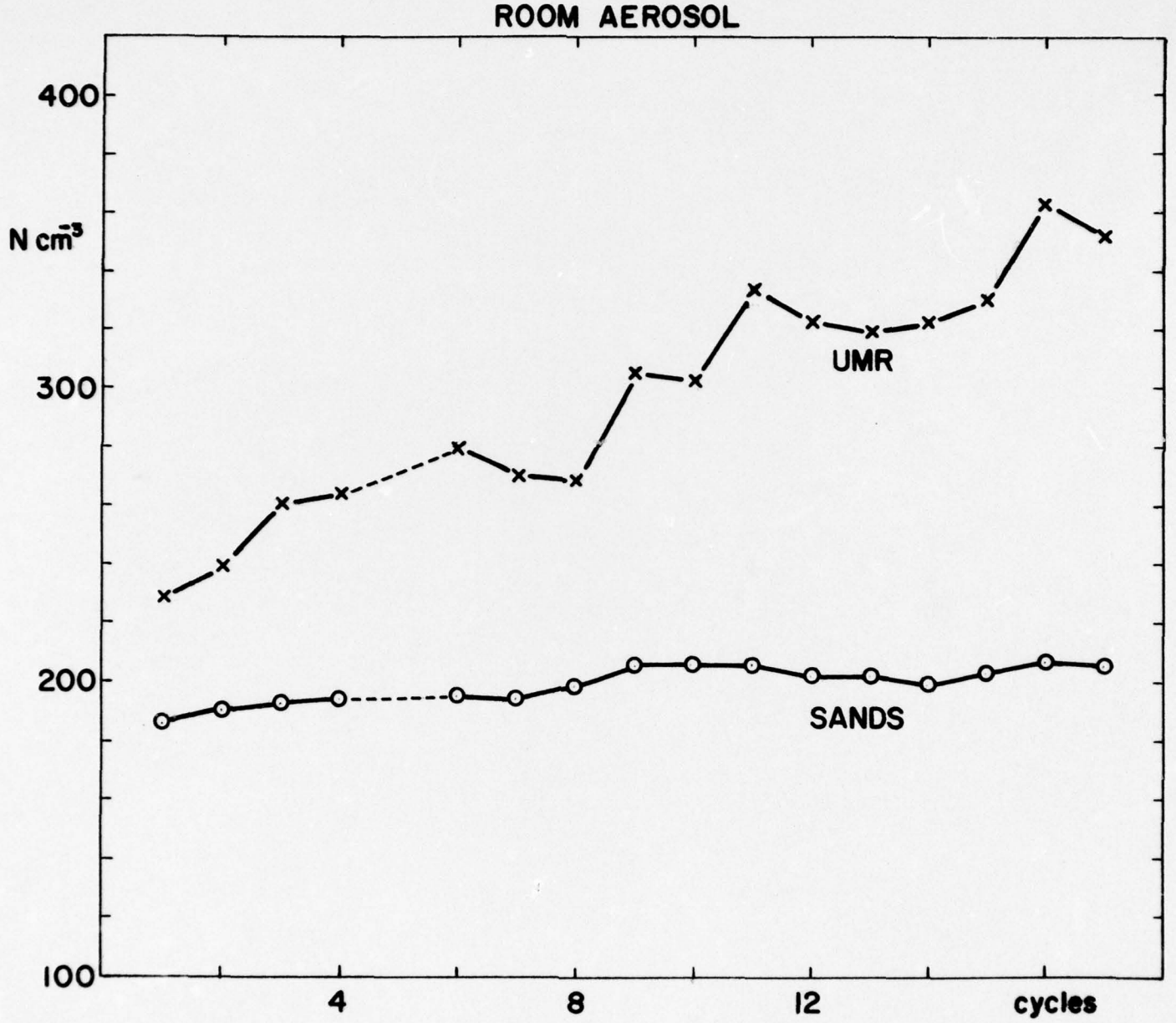

FIG. 6

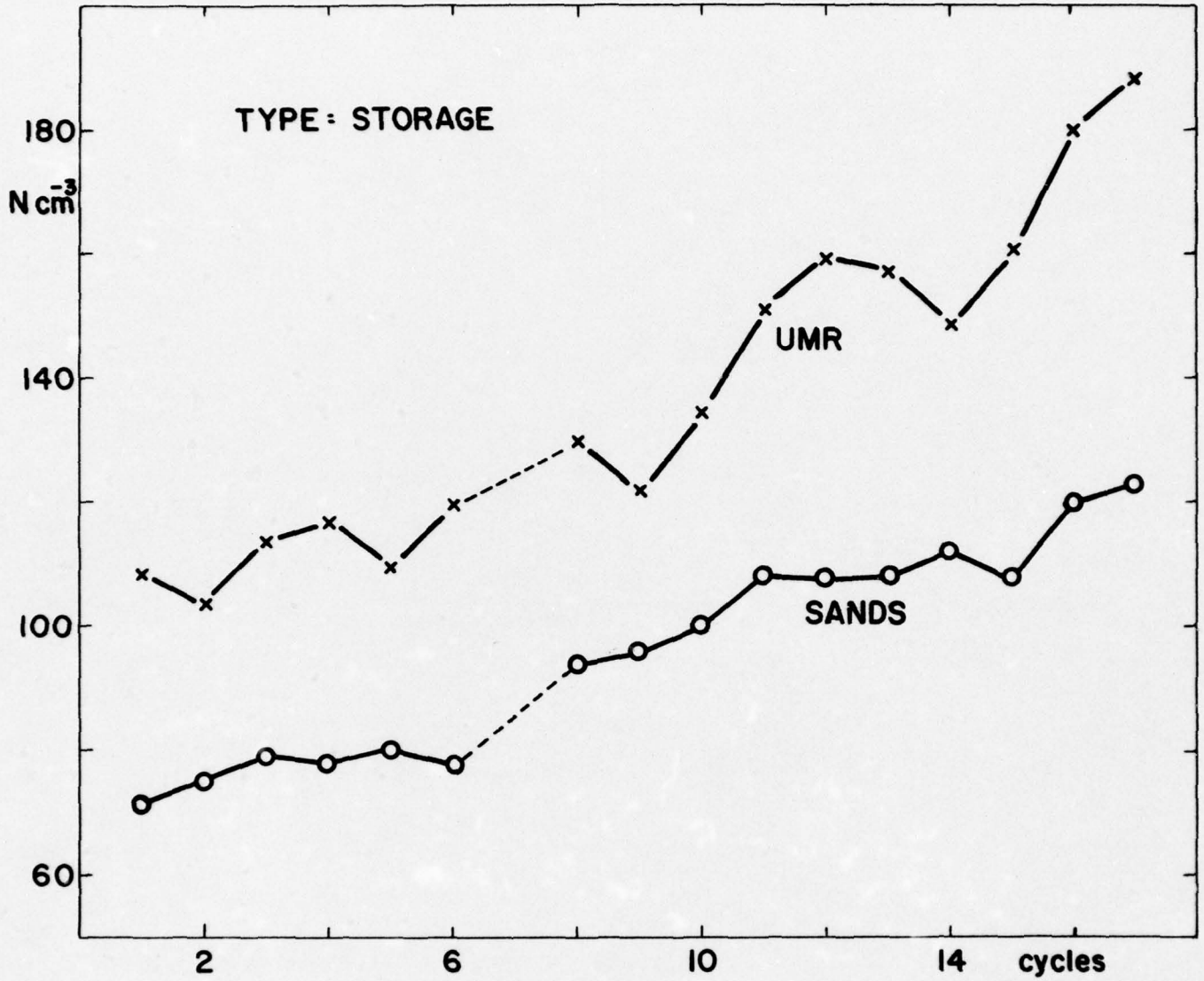

FIG. 7

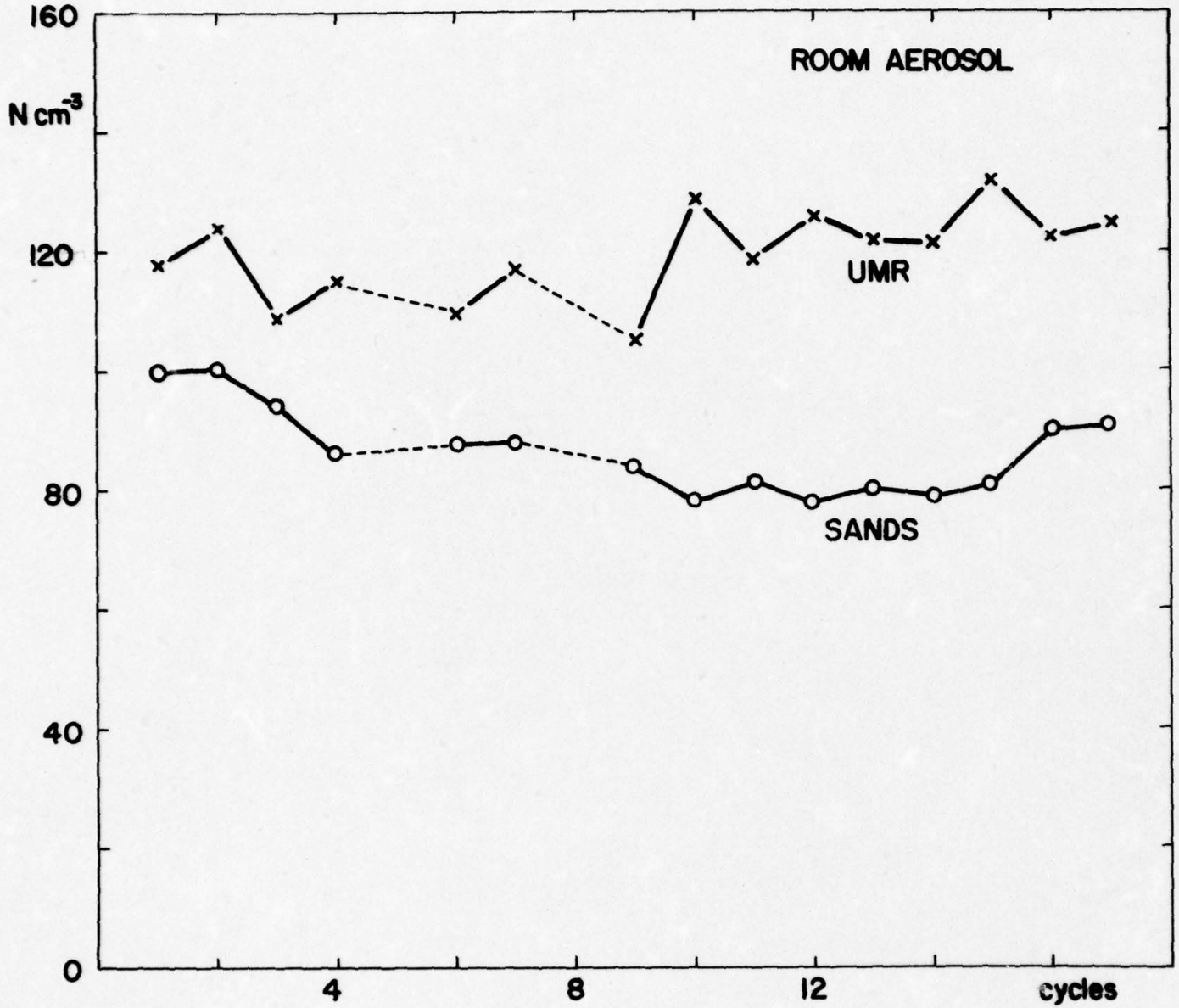

FIG. 8

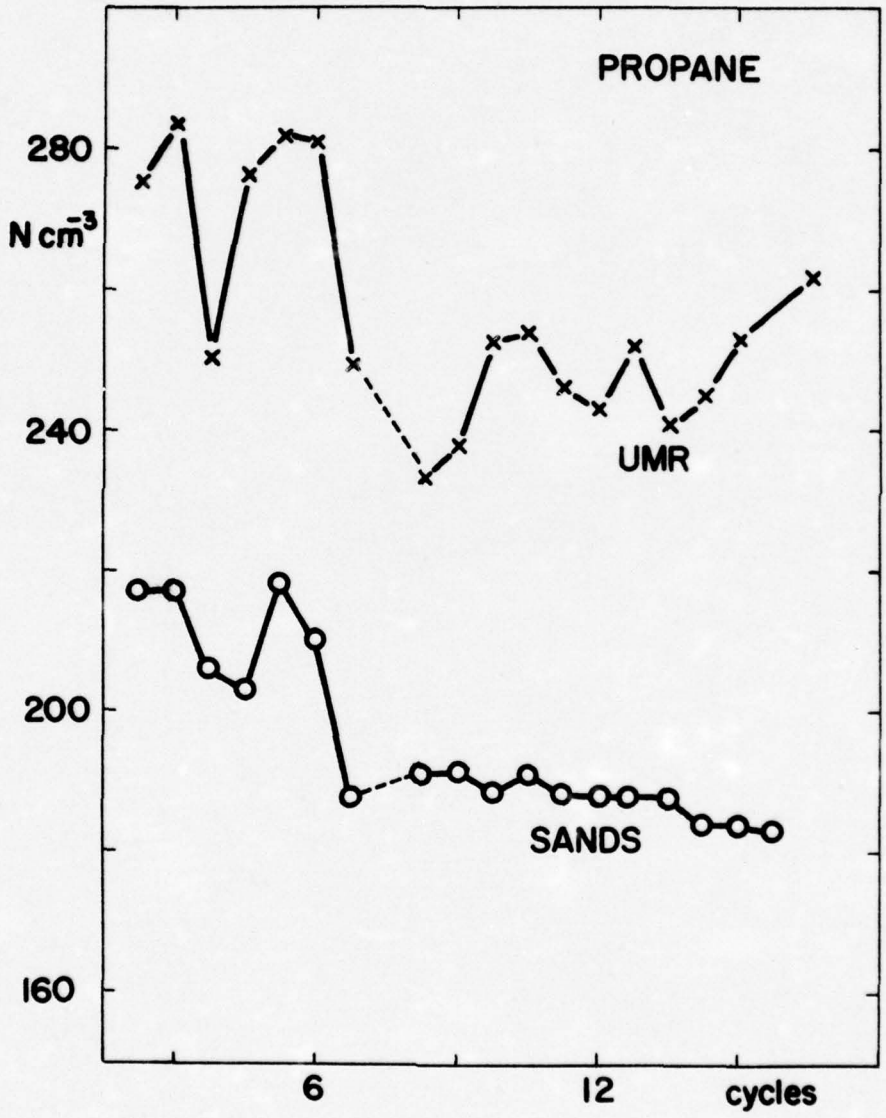

FIG. 9

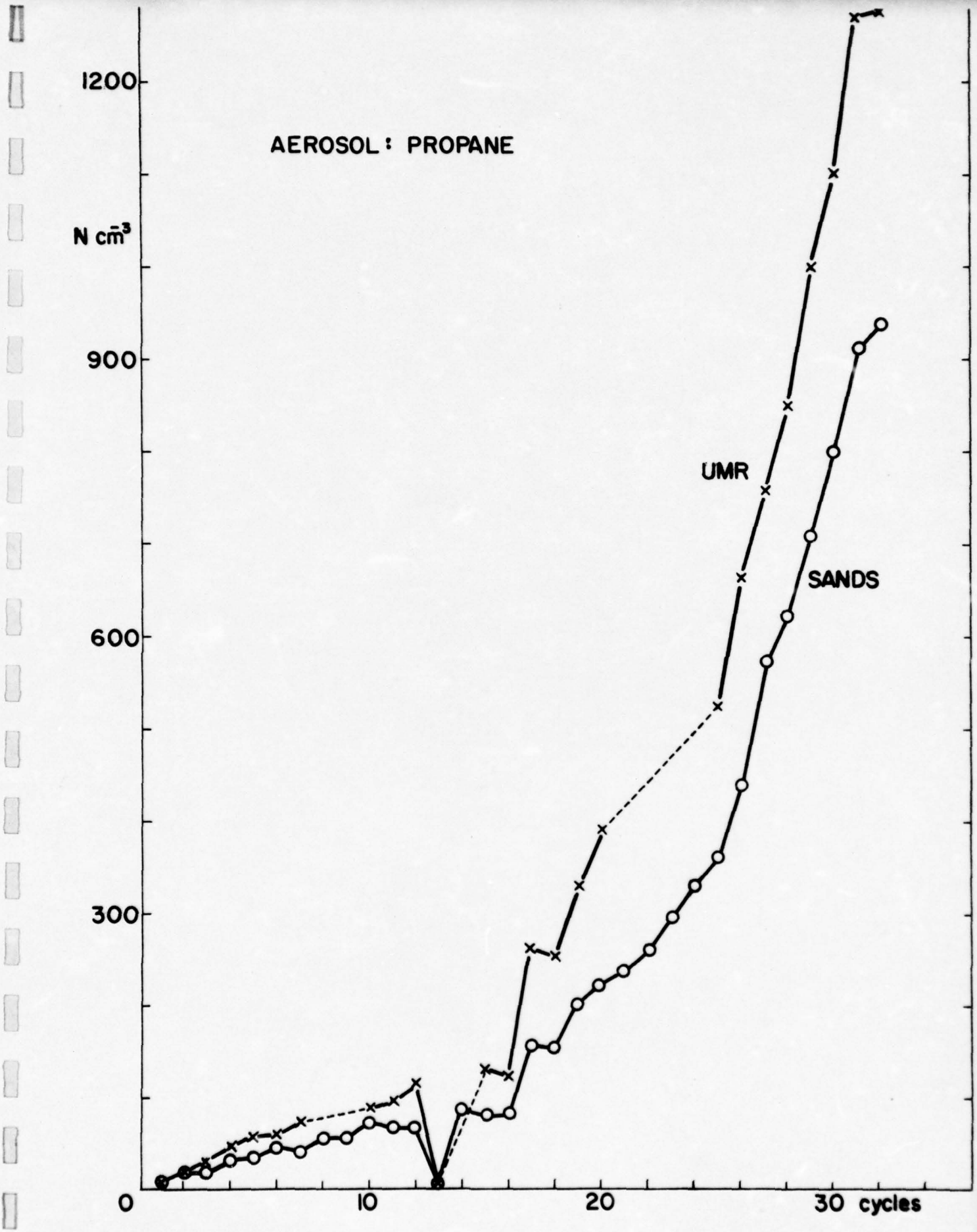
AEROSOL: PROPANE
N cm⁻³
1200
900
600
300
0
10
20
30 cycles
UMR
SANDS

FIG. 10

REPORT ON THE SECOND CALIBRATION OF THE STRATOSPHERIC AITKEN NUCLEI DETECTION SYSTEM (SANDS).

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Graduate Center for Cloud Physics Research
University of Missouri-Rolla, Rolla, Mo. 65401

ABSTRACT

The Report on the Second Calibration of the Stratospheric Aitken Nuclei Detection System (SANDS) describes the testing of the SANDS, which was done in the laboratories of the Graduate Center for Cloud Physics Research at the University of Missouri-Rolla at the end of 1974. These series of measurements made after the adjustment of the SANDS and after the first testing of the instrument in the first half of 1974, are characterized by: a) a high sensitivity of the counter (around 5 particles per cm^3), b) good response to the UMR-ANC (correlation coefficients were higher than 0.809 for four different aerosols), c) satisfactory reproducibility of data within an acceptable error range (estimated standard errors were lower than 12% of the measured values of the AN concentrations). The use of different aerosols is documented by a detailed analysis of the size distribution spectrum of gold and sodium chloride aerosol and by the electron micrographs of the particles.

INTRODUCTION

The first comparison between the SANDS and the University of Missouri - Rolla Aitken nuclei counter (UMR ANC) was made at the beginning of 1974. In November of 1974 the SANDS was slightly modified and its performance checked during three flights on the WB-57F aircraft. Therefore, a second calibration was necessary before the SANDS, along with other instruments, was installed into the aircraft for a new mission in 1975.

CALIBRATION PROCEDURE

The calibration of the SANDS without the Pressurization Unit by the UMR-ANC, was performed much the same way as the first comparison. The only difference was the absolute data measured by SANDS was closer to that measured by UMR-ANC as a result of the new adjustment of the SANDS instrument. The second calibration was also extended into higher AN concentrations (up to 30,000 particles per cm^3). Also, in the second comparison, better defined aerosols were used. Nuclei generated by the evaporation of propane and AgI aerosol were replaced by nichrome and gold particles. Nichrome particles were generated from a heated wire in a nitrogen gas flow. After eliminating the coarse particles, the aerosol was introduced into the 18 m^3 storage chamber which was described in the previous report. The gold particles were generated by the exploding wire technique. A 0.002 inch pure gold wire was fastened between two electrodes one inch apart. The gold was vaporized by discharging a 9μF capacitor at 4000 volts through the wire. Two pumps were used to dilute the aerosol to a concentration of less than 100,000 particles per cm^3 in

a 50 liter chamber. From this chamber the gold aerosol was sucked into the large 18 m^3 storage room where it remained for twenty four hours before a comparison run was made.

Sodium chloride aerosol was prepared, unlike the aerosol for the first calibration, by bubbling nitrogen gas through a salt solution (5 mg in 1 ml of distilled water) at a flow rate of three liters per minute. After passing through the heated drift tube the aerosol was stored in a smaller mylar bag of 0.56 m^3 volume. Usually, before the calibration run was started, samples of aerosols for electron microscopical investigation were taken directly from the mylar bag with the aid of an electrostatic precipitator.

Two nichrome aerosols were evaluated separately because of the different times of their preparation and because of the necessity to adjust the flash system in the UMR AN counter just prior the series of measurements with the aerosol denoted by "Nichrome 1" in Table I.

Fig. 1 shows the spectrum distribution of gold and of sodium chloride particles as they are measured under an electron microscope. The modal size (diameter) of the gold aerosol was 0.025μm and of the sodium chloride aerosol, 0.13μm. The monodispersity factor corresponds in the first case to $\alpha = \frac{\sigma}{\bar{r}} = 0.532$ and in the second to $\alpha = 0.322$. However, many of the gold particles were aggregated (Fig. 2, 3). This means that the size distribution spectrum curve does not reflect the true number of particles which acted as condensation nuclei. Sodium chloride nuclei, which represent the upper size ranges of AN, were also found coagulated. However, these were in a

less uniform state than the gold particles (Fig. 4, 5). Despite these deficiencies, the generated aerosols during the second comparison of instruments were better defined than those of the first calibration. This is apparent from the values of parameters characterizing the response of both instruments found in Table 1 and from the individual runs of the calibration (Fig. 6 to 11).

RESULTS OF THE CALIBRATION

The correlation coefficient r_{xy} and the estimated standard error (E.S.E.) were chosen as parameters describing the response of the measurements made by the SANDS and by the UMR-ANC. The procedure used for the calculation of these parameters was the same as that described in the first report except the nuclei concentration groups were divided into six concentration ranges between 0-100; 100-300; 300-1000; 1000-3000; 3000-10000; and 10000-30000 particles per cm^{-3}. Each of these groups were treated separately for all four aerosols. It was necessary to include the higher concentration ranges because higher AN concentrations were found during the first flights (intercepts with the contrails) than were originally anticipated.

Table I is similar to that in the first report except the calculated ratio $\overline{X}/\overline{Y}$ corresponds to $\overline{Y}/\overline{X}$ in the first report. It shows that the main attention was paid to AN concentrations between 100 and several thousands. Relatively few runs were made at the concentration below 100 nuclei per cm^{-3} (two comparisons of nichrome aerosol and three of gold aerosol). The deviations of the readings of both instruments were larger at these lower

concentrations than at higher concentrations. The reason for this was the lower accuracy of the evaluation of the photographs of the droplets in UMR-ANC which resulted in larger statistical errors. Also the detection of very low drop concentrations in the SANDS counter by light scattering measurement was always characterized by larger fluctuations of the signal. In mean, the response of the counts of both instruments was better in the second calibration due to the superior quality of the aerosols used. The correlation coefficient and E.S.E. were not calculated for the lowest range of AN concentration because there was not a sufficient number of pairs of simultaneous counts. At higher AN concentrations the highest values of r_{xy} were found for nichrome 1 and gold aerosol (0.93), and the lowest values of the correlation coefficient corresponded to nichrome and sodium chloride aerosol (0.85). The ratios of the E.S.E. and of the mean AN concentrations measured by SANDS were lowest in the case of gold and sodium chloride aerosol (in mean 5%). The highest value of this ratio (12.07%) was found in the case of nichrome 1 aerosol which can be explained by the adjustment of the flash system of the UMR counter.

In general, the counts of sodium chloride AN were characterized by a high reproducibility of data. This is explained by the fact that aerosol was generated for the second series of measurements by bubbling nitrogen gas through a salt solution which delivered cubically shaped sodium chloride crystals (Fig. 4, 5) containing no impurities. This was unlike the generation of the sodium chloride particles for the first series of measurements which were generated by an ultra-acoustic mist-generator. The

formation of oxides on the surface of nichrome particles, generated by electrically heating a nichrome wire, might be responsible for the relatively low response of both instruments to the absolute counts. However, none of the calculated correlation coefficients of the second calibration of SANDS were lower than 0.80. The close mean AN concentrations measured by SANDS ($\bar{Y}$) and by the UMR-ANC ($\bar{X}$) were due to the mentioned adjustments of the SANDS.

CONCLUSIONS

The second calibration of the SANDS yielded similar results to the previous one. There was a satisfactory reproducibility of data and high sensitivity of the SANDS which is apparent in Fig. 6 to 11. The SANDS instrument in comparison with the UMR-ANC always showed a high correlation of counts. The lowest value of the correlation coefficient was 0.809 and was measured with rather large sodium chloride nuclei. The best results were obtained with the gold aerosol which had an acceptable degree of monodispersity (based on the evaluation of electron micrographs). Because of the intention to calibrate the SANDS at concentrations higher than 50 particles per cm^3, there were only a few measurements at concentrations below 100 particles per cm^3. The pairs of data at those small concentrations naturally showed the largest deviations. The ratio of the counts by UMR-ANC and by SANDS never exceeded the value of 1.20 (1.198 for nichrome and 1.157 for gold aerosol).

In general, the E.S.E. for different nuclei concentration ranges, was smaller than 12% of the measured AN concentration.

In the case of gold aerosol, nichrome, and sodium chloride aerosol, they were smaller than 6.6%.

ACKNOWLEDGEMENTS

The authors of this report appreciate the assistance of J. B. Haberl from General Electric Corporation in Pittsfield, Massachusetts. They are indebted to M. Podzimek, S. Shults, P. Christman, R. Elliott, and D. Koonce for their technical help.

The financial support of this work by the United States Department of Transportation through the NAVY (contract ONR N00014-75-C-0413) is gratefully acknowledged.

TABLE I.

Aerosol	Range	No. cases	$\bar{X}$	$\bar{Y}$	$\frac{\bar{X}}{\bar{Y}}$ %	r_{xy}	b_0	b_1	E.S.E.	$\frac{\text{E.S.E.}}{\bar{Y}}$ %
Nichrome 1	300-1000	10	627.3	598.0	104.9	0.94760	-115.99	1.13820	76.970	12.071
	1000-3000	4	1467.5	1395.0	105.2	0.99267	90.94	0.88863	164.255	11.775
Sodium Chloride	1000-3000	8	2730.6	2417.5	113.0	0.81009	543.60	0.68626	75.628	3.128
	3000-10000	21	6803.0	6619.0	102.8	0.98695	-290.60	1.01567	432.416	6.533
	10000-30000	11	11122.2	10854.5	102.3	0.80902	2495.7	0.75154	320.25	2.950
Nichrome	0-100	2	57.5	48.0	119.8					
	100-300		243.7	231.6	105.2	0.82046	7.99	0.91752	10.667	4.607
	300-1000	3	394.3	380.0	103.8	0.88815	157.44	0.56445	22.240	5.853
Gold	0-100	3	24.67	21.33	115.7					
	100-300	13	260.6	243.2	107.1	0.93234	46.24	0.75584	10.054	4.134

LIST OF FIGURES

Figure

1 Size spectrum distribution of gold and sodium chloride particles measured under an electron microscope.

2 Electron microphotograph of gold aerosol. Magnification 22,500.

3 Electron micrograph of gold aerosol. Magnification 22,500.

4 Electron micrograph of NaCl aerosol. Magnification 22,500.

5 Electron micrograph of NaCl aerosol. Magnification 22,500.

6 Calibration with nichrome 1 aerosol.

7 Calibration with sodium chloride aerosol.

8 Calibration with sodium chloride aerosol.

9 Calibration with sodium chloride aerosol.

10 Calibration with nichrome particles.

11 Calibration with old aerosol.

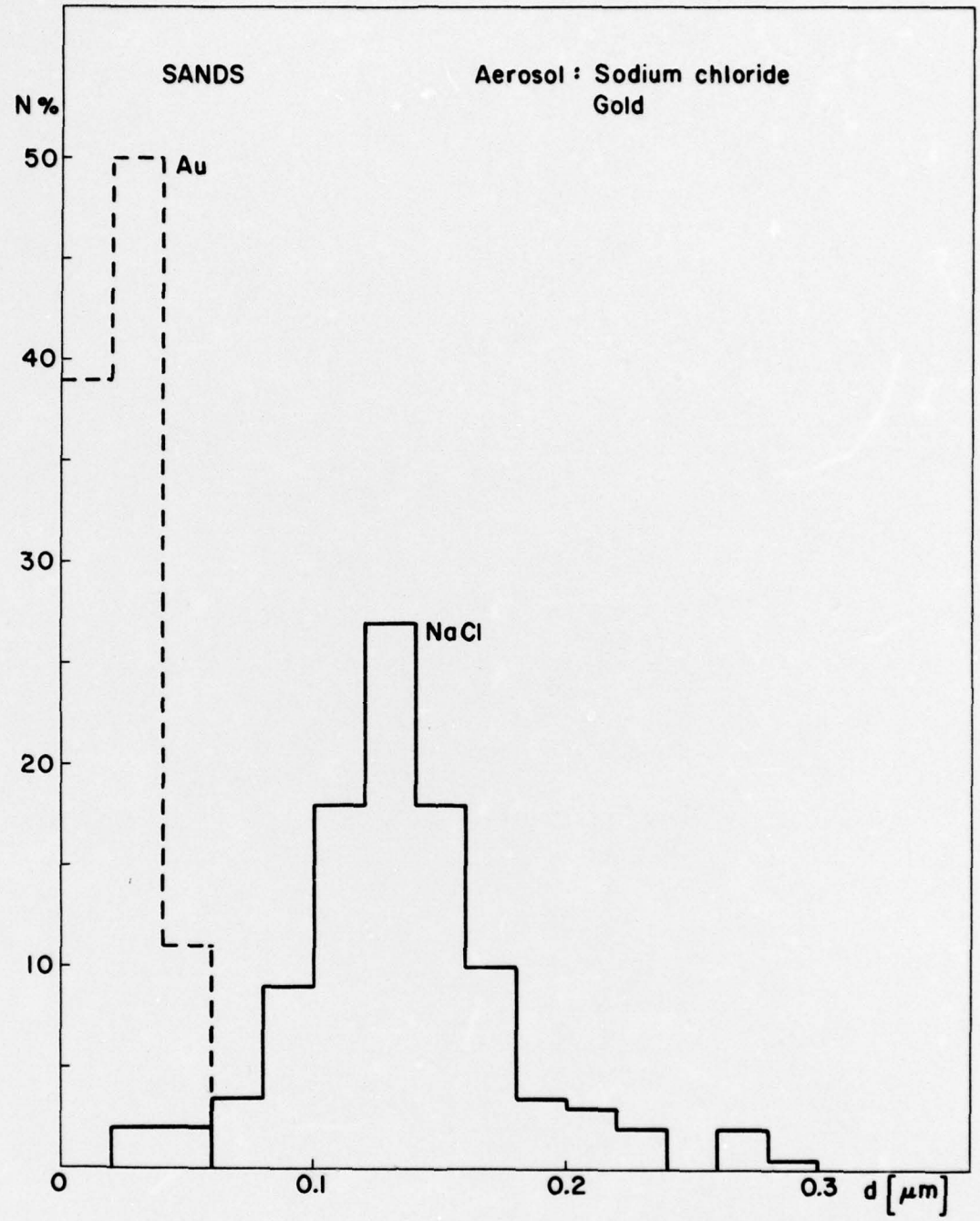
SANDS
Aerosol : Sodium chloride
Gold
N %
50
40
30
20
10
0
Au
NaCl
0.1
0.2
0.3
d [μm]

FIG. 1

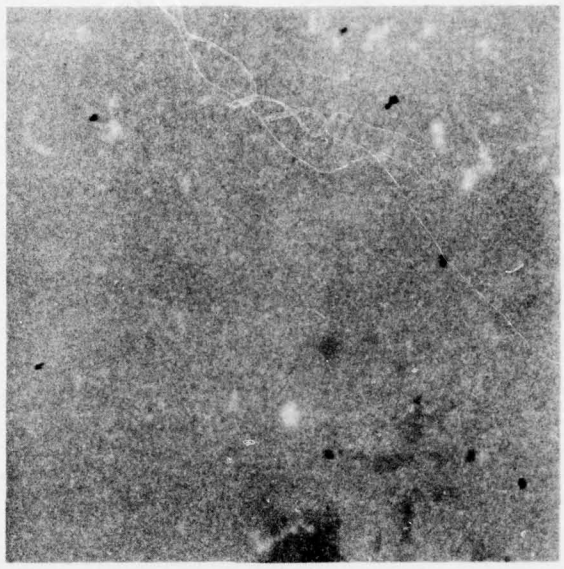

FIG. 2

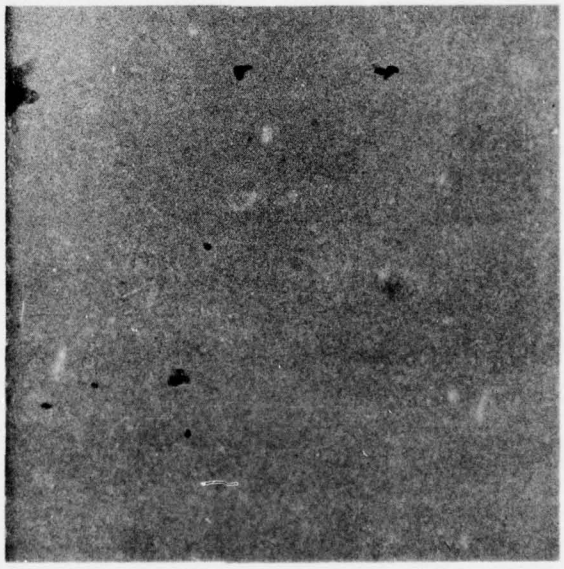

FIG. 3

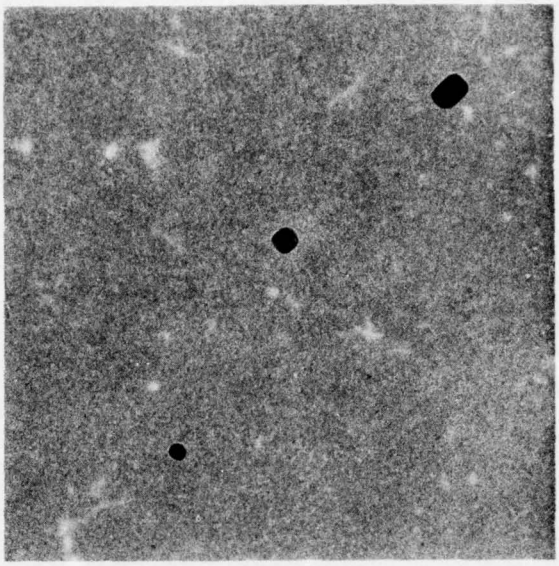

FIG. 4

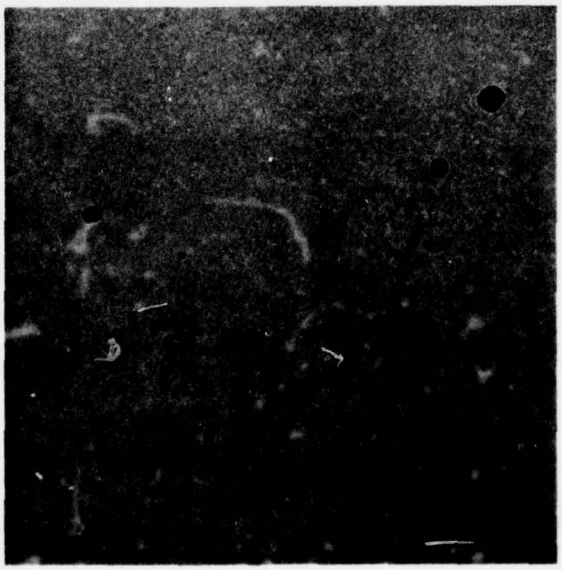

FIG. 5

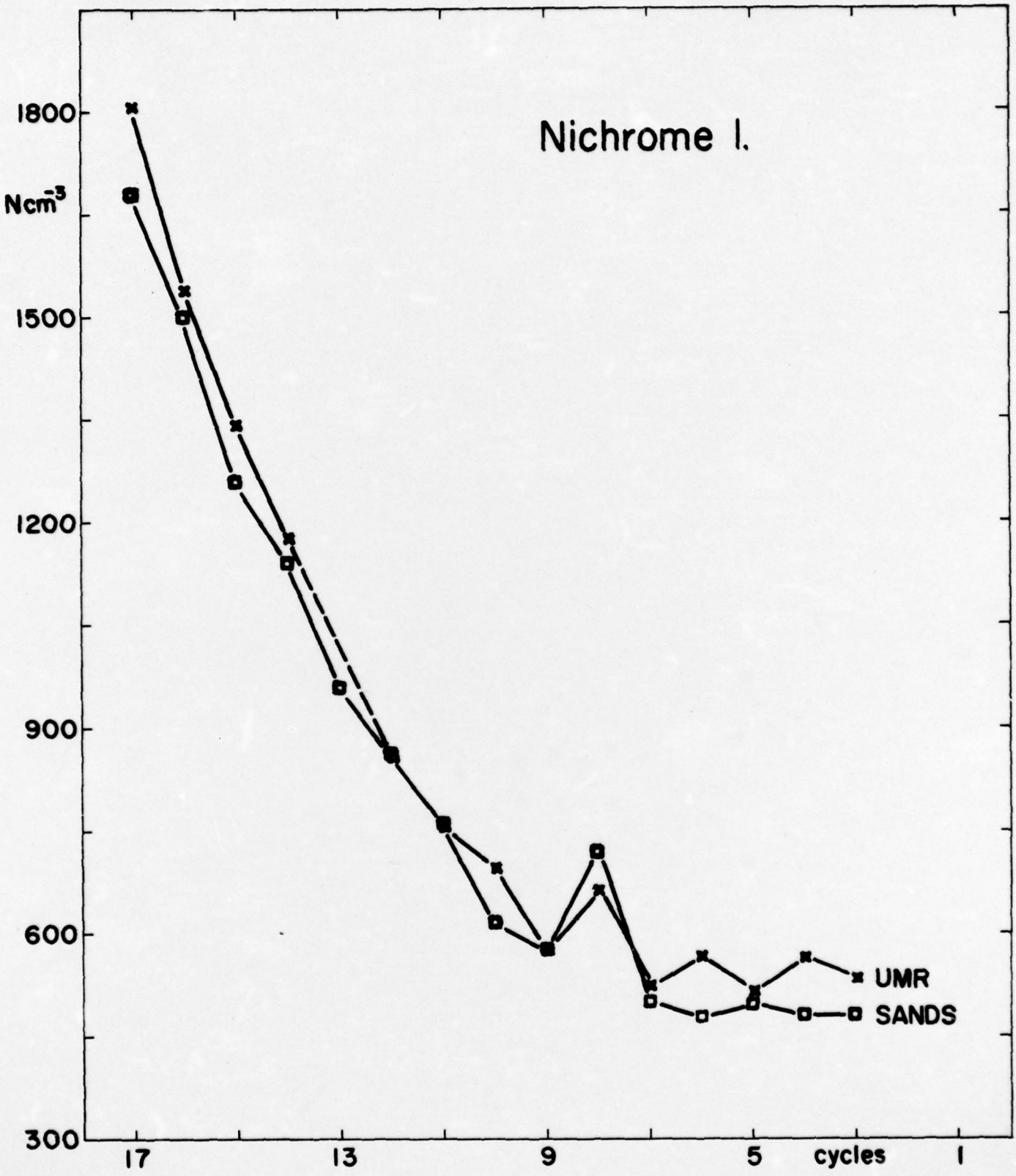
Nichrome I.
1800
Ncm⁻³
1500
1200
900
600
300
17
13
9
5
cycles
1
UMR
SANDS

FIG. 6

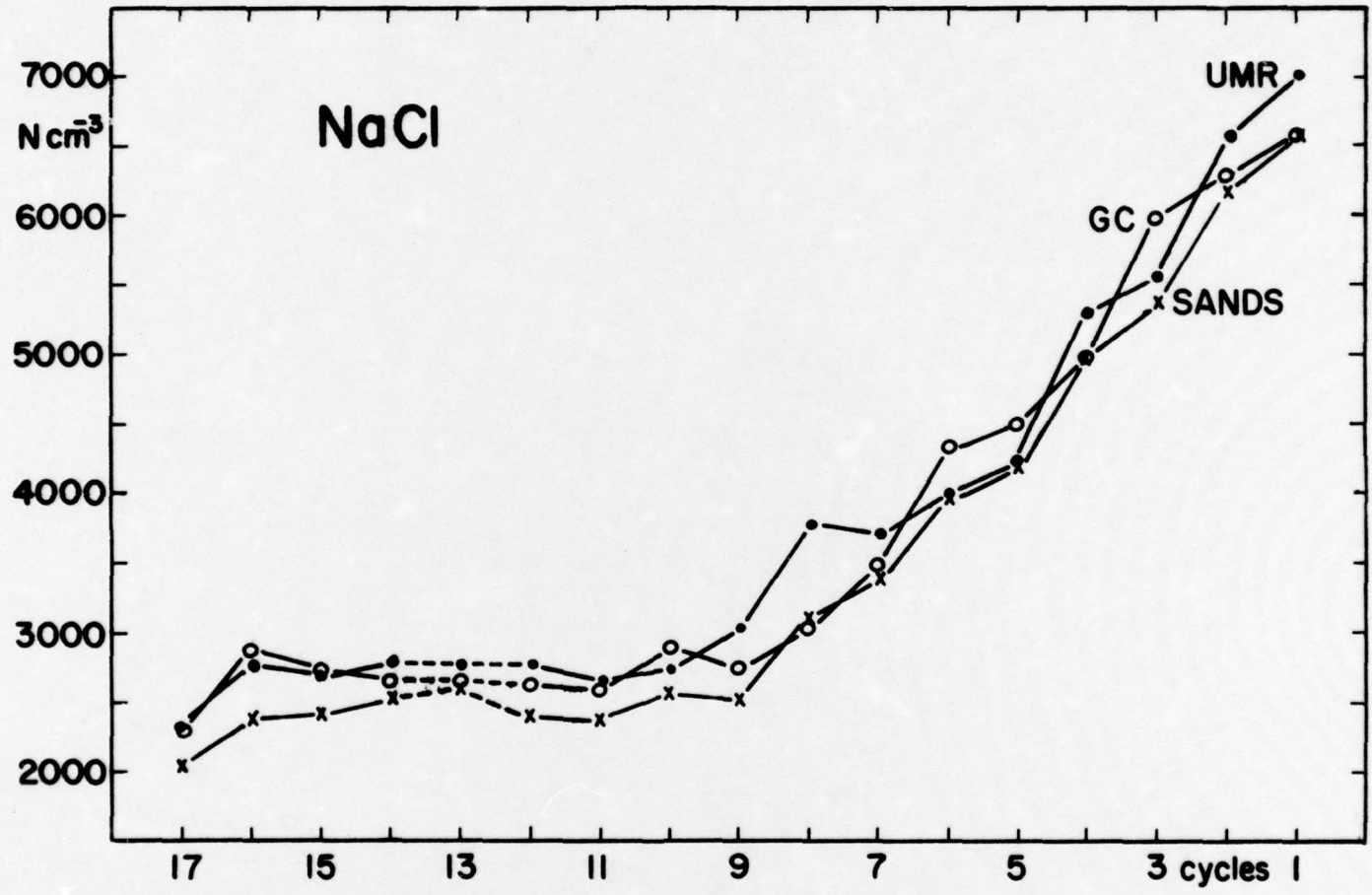
NaCl
7000
N cm⁻³
6000
5000
4000
3000
2000
UMR
GC
SANDS
17
15
13
11
9
7
5
3 cycles 1

FIG. 7

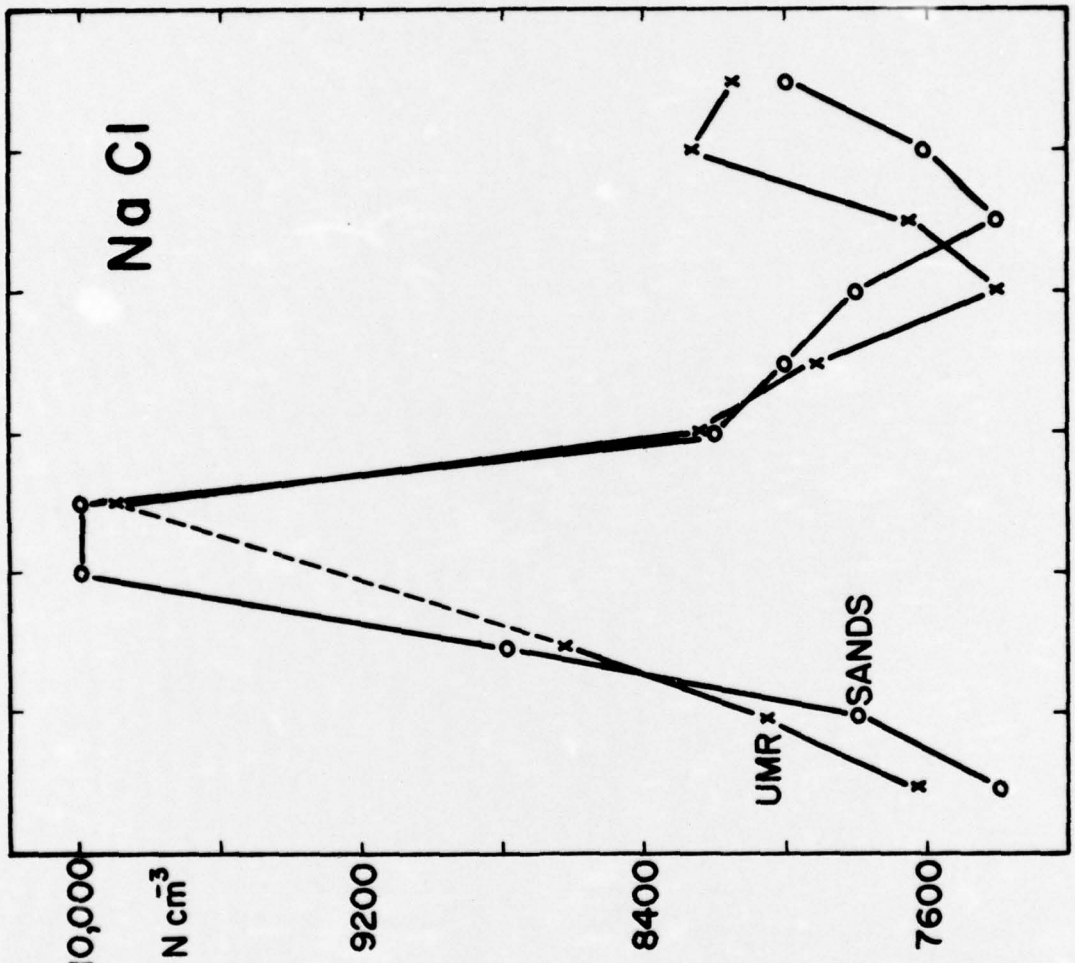

FIG. 8

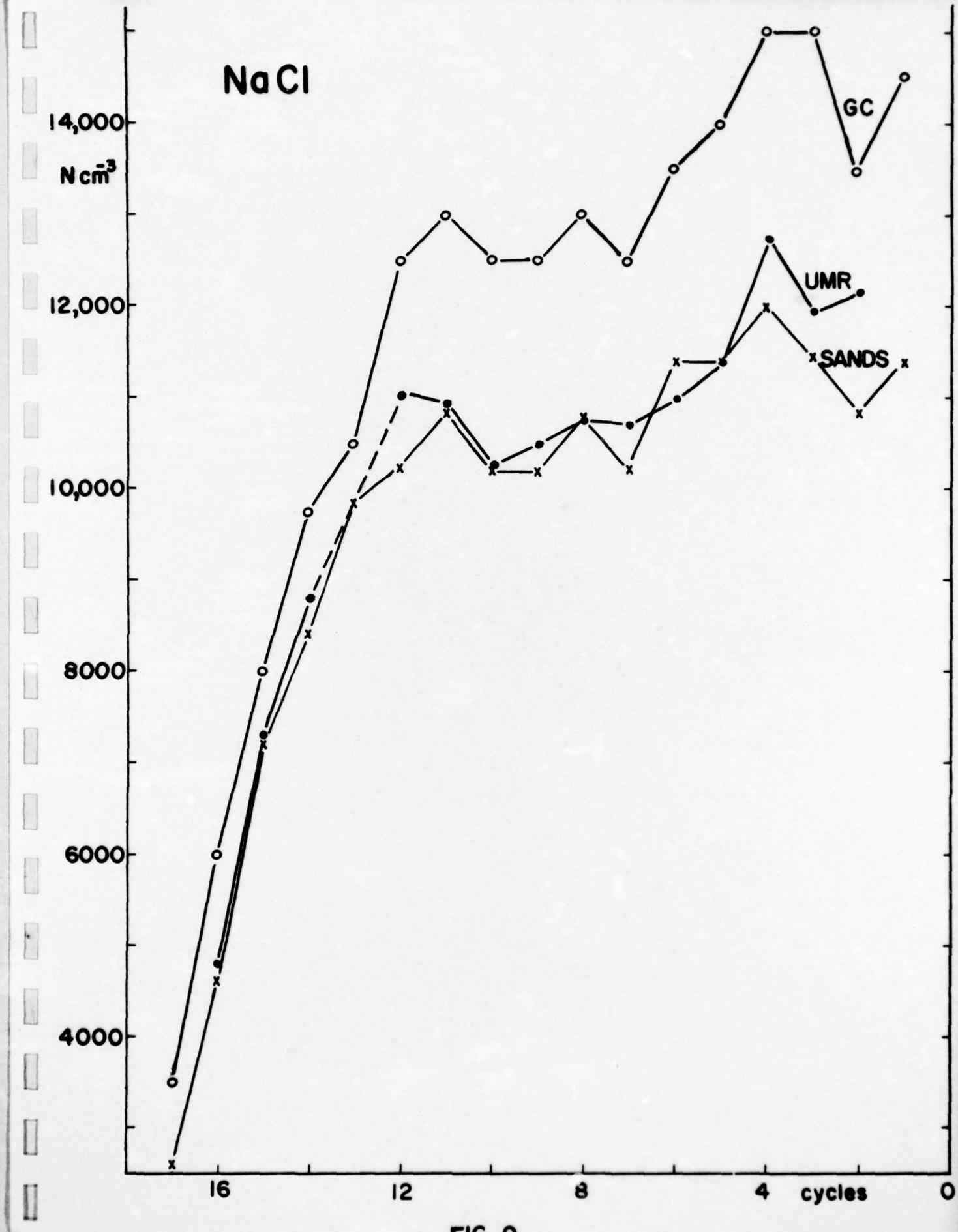
NaCl
14,000
N cm⁻³
12,000
10,000
8000
6000
4000
GC
UMR
SANDS
16
12
8
4
cycles
0

FIG. 9

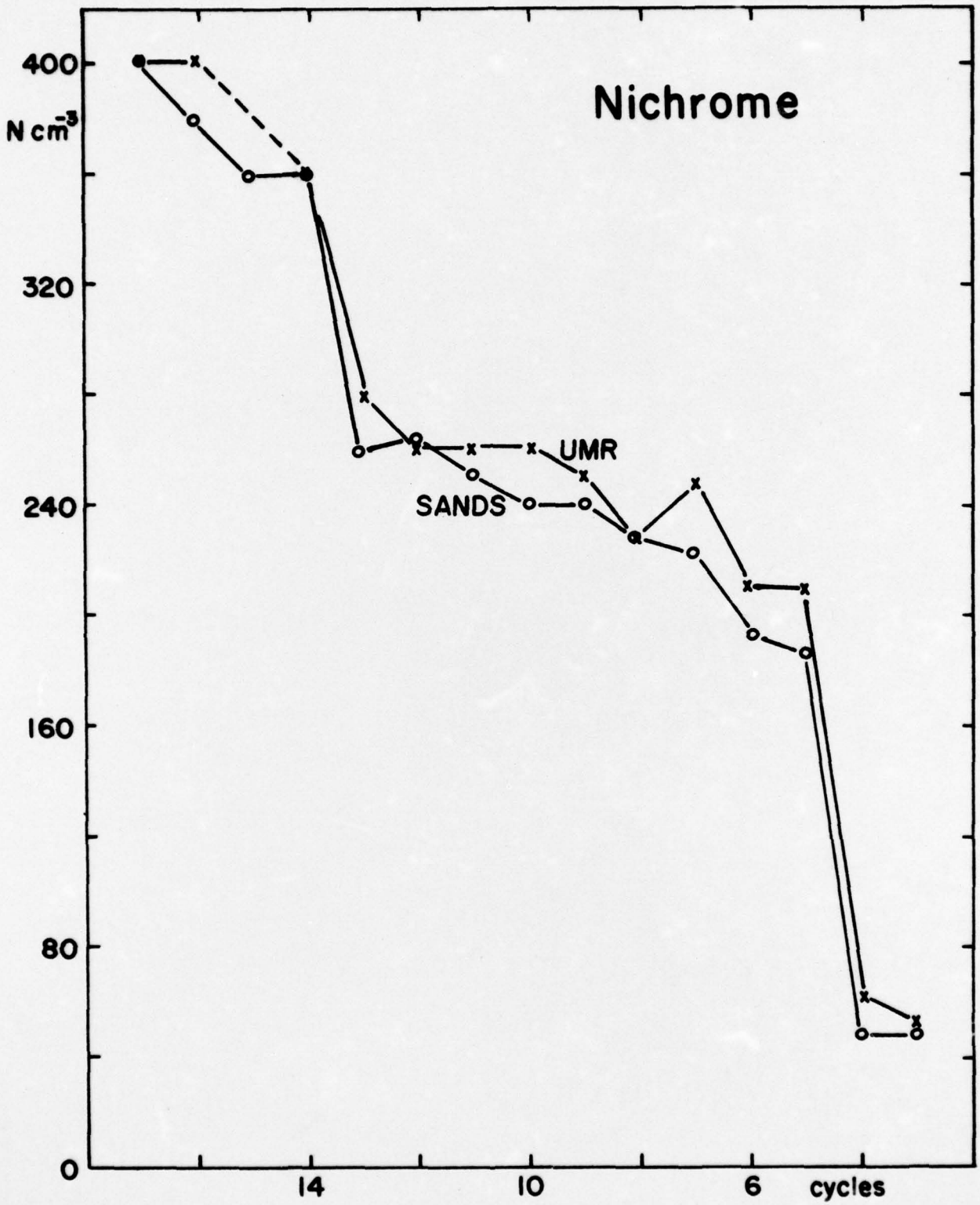

FIG. 10

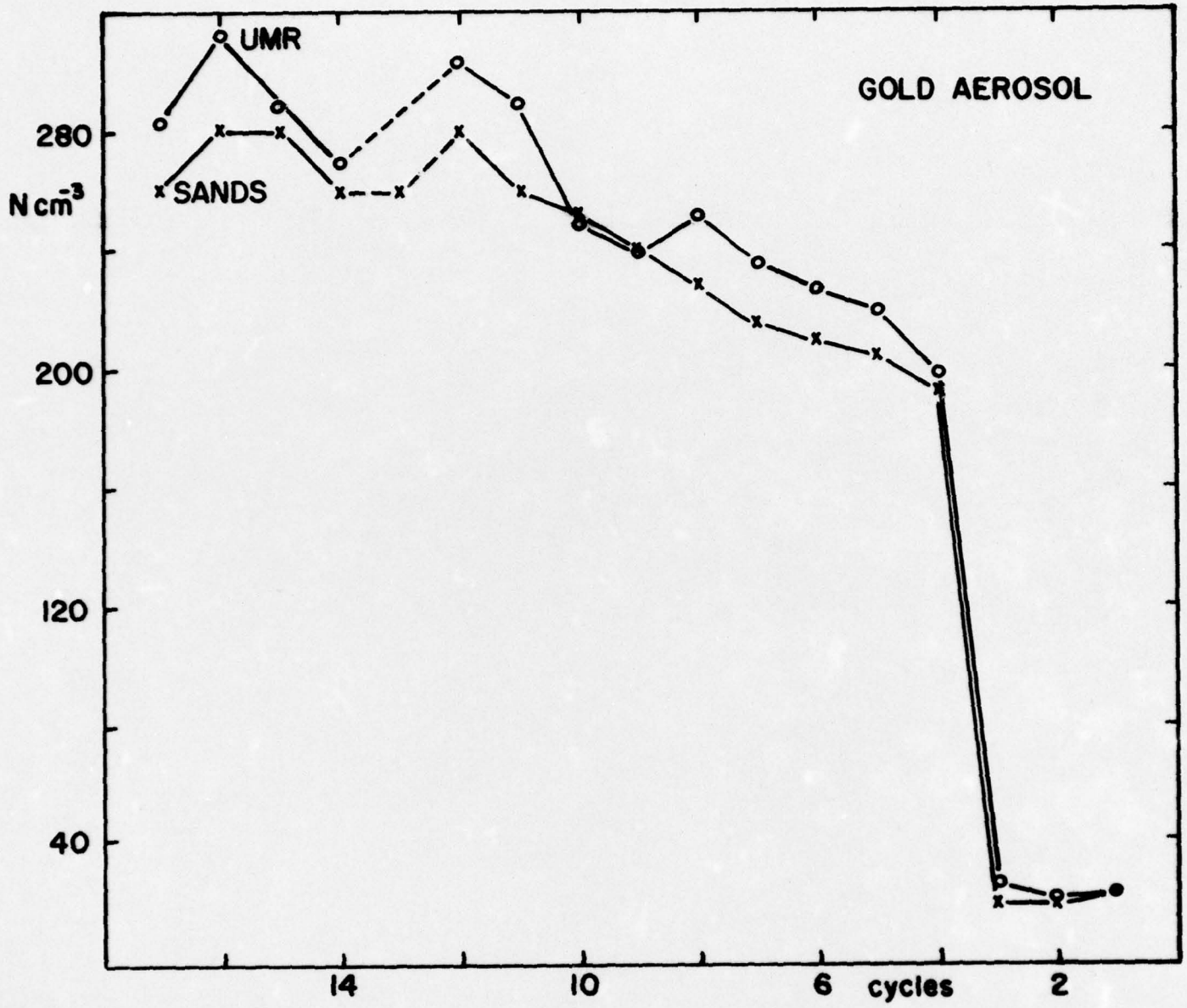

FIG. 11